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(56) Documents Cited
GB 2327834 A GB 2274759 A GB 2256985 A
EP 0719013 A2 EP 0693750 A2 EP 0692894 A2
EP 0594894 A1 EP 0474615 A2 EP 0430480 A2
WO 98/16039 A1 WO 98/10523 A1 WO 98/06172 A1
WO 98/01981 A1 US 5748681 A

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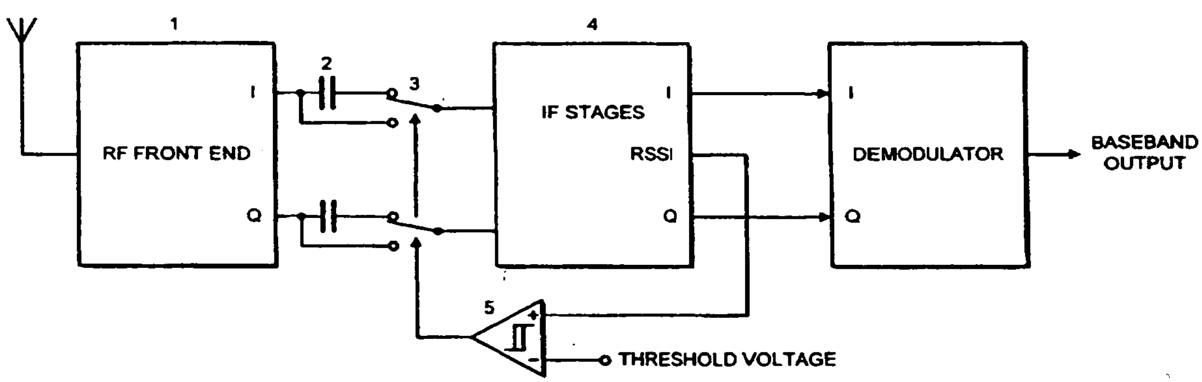
(54) Abstract Title

DC offset correction in a direct conversion receiver

(57) A method for controlling DC offset correction in a direct conversion receiver of a portable radio communication apparatus, the receiver having means (1) for down converting a received radio frequency signal to a down converted signal, comprises measuring the signal strength of the received signal, providing a signal indicative of the signal strength of the received signal (RSSI), comparing (5) said signal indicative of the signal strength of the received signal to a predetermined threshold value of signal strength and applying DC offset correction for correcting the down converted signal if said signal indicative of the signal strength of the received signal is below the predetermined threshold and disconnecting (3) DC offset correction for the down converted signal if the signal indicative of the signal strength of the received signal exceeds the predetermined threshold value of the signal strength. AC coupling is switched in or out of circuit according to the Received Signal Strength Indication (RSSI) or, alternatively, a servo loop is switched out at high SNR and activated at low SNR to provide the DC offset correction.



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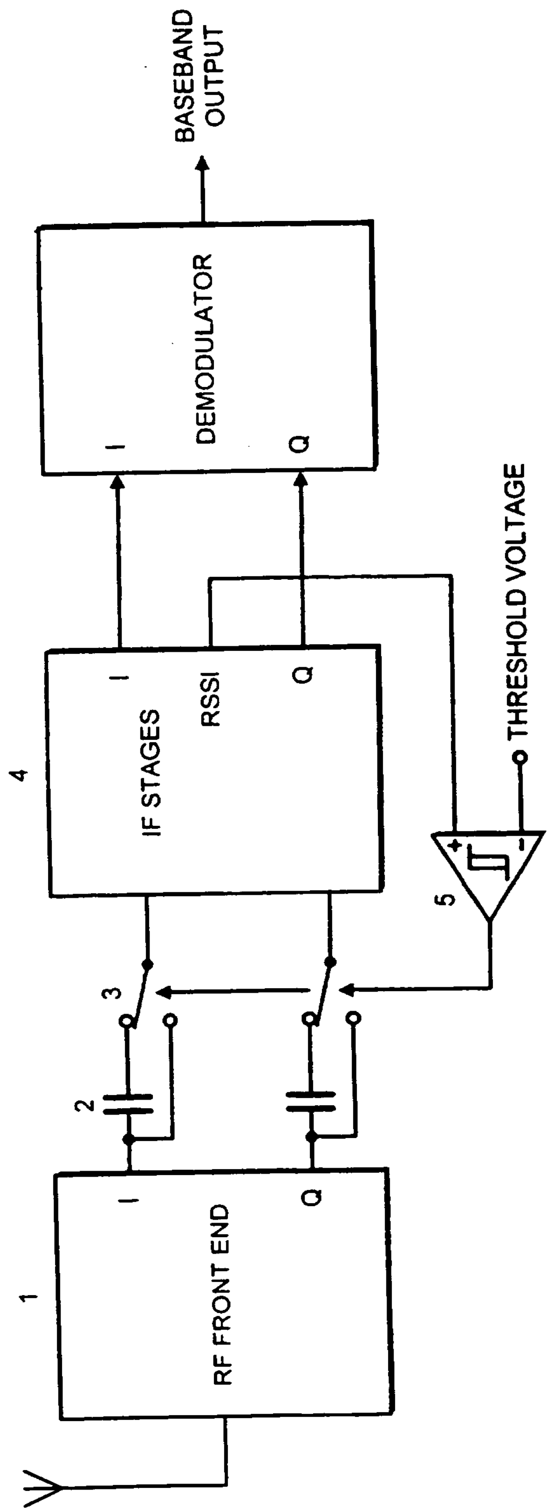
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.


BASEBAND OUTPUT
DEMODULATOR
I
Q
4
IF STAGES
I
RSSI
Q
THRESHOLD VOLTAGE
5
3
2
1
RF FRONT END
I
Q

DC Offset Correction in a Direct Conversion Receiver

The present invention relates to a portable radio communication apparatus, and more particularly to DC offset correction in a direct conversion receiver of such apparatus.

A general trend in portable radio communication apparatus is the reduction in volume, weight and power consumption of such apparatus. This has led to efforts towards reducing the number of elements and devices necessary to perform the functions associated with portable communication devices. In particular, the radio frequency front end of portable apparatus, which typically comprises a number of down-converting stages, is an area in which a reduction in the number of elements and devices would be beneficial.

One approach to reduce the number of stages in the radio frequency front-end is to convert a received radio frequency carrier signal down to a DC Intermediate Frequency (zero IF) in a single step. This is termed direct conversion and is carried out in receivers known by any one of the terms homodyne or zero IF receivers, as well as direct conversion receivers. In a Direct Conversion Receiver, received radio frequency signals are converted directly into base band signals, so that separate intermediate frequency stages are not required. Therefore, the number of higher frequency components needed in a direct conversion receiver is less than in conventional receivers which will include intermediate frequency stages. Due to less complexity, the degree of integration of direct conversion receivers can be increased compared to receivers which must include intermediate frequency stages.

To carry out direct conversion, a local oscillator signal (LO) having the same frequency as the radio frequency carrier signal (ie. the LO is "on-channel") is mixed with the carrier signal in a suitable non-linear device such as a mixer diode. The output of the mixer contains the sum and difference of the LO and the carrier signal. Thus a mixer product exists at twice the carrier signal, and also at DC (zero Hz). The high frequency mixer products can be filtered by a suitable low pass filter. Once the radio frequency carrier signal has been down-converted, the modulating signal may be de-modulated using an appropriate demodulator, e.g. an I/Q demodulator for an I/Q modulating signal, or an FM demodulator for an FM signal.

In the field of radio telephony, particularly cellular telephony, use of a direct conversion receiver is not without certain drawbacks.

One of the main problems of using a direct conversion receiver in a cellular radiotelephone, a problem that is widely recognised, is that of DC voltage offset. DC offset basically consists in unwanted DC being provided at the output of the RF front-end stage which if large enough causes distortion to the wanted signal. Because DC is encompassed in the IF bandwidth, the DC offset present at the RF front-end output and that contributed by IF amplifiers severely limits the sensitivity of the receiver if it is not removed. Low frequency AC such as flicker noise and spurious AM demodulation can also cause similar problems.

The dynamic range of the receiver is adversely effected by the fact that in addition to the high frequency signal of the reception channel, the mixer of the receiver also receives high frequency signals of the adjacent channels, whereby due to the non ideality of the mixers, a disturbing DC offset is produced at the output of the mixer. Thus a stronger signal of the adjacent

channels can produce substantially higher DC offset in the signal than the desired signal expressed on the reception channel.

A number of different methods to solve the problem caused by DC offset have been investigated. The most common of these are: AC coupling, closed loop servo correction, and DC averaging and removal.

AC coupling is the simplest approach. The IF stages are AC coupled which removes the DC voltage and low frequency noise, and stops it from propagating up to the highest gain stages. However it introduces a notch into the centre of the IF pass-band. In the case of modulation such as FM, the carrier term is removed so distortion is introduced to the required signal. This is a significant problem with direct conversion: the interference cannot easily be differentiated from the wanted signal. Often a major problem with AC coupling is that the coupling capacitors can take a significant time to charge up which means that the receiver can take tens of milliseconds to settle. Pre-charging techniques are typically required. When a narrow band filter is used the settling time becomes long whereby the filter cannot react to quick changes of power. On the other hand with a wide band filter it is possible to achieve a short settling time, but a filter of this kind also filters a substantial part of the useful signal whereby the performance of the receiver is reduced.

Closed loop servo-correction has been used in audio amplifiers to remove offset voltages. It can also be used in a direct conversion receiver to remove the DC offset created in cascaded IF stages and the mixers. Careful design is required to ensure stability.

DC averaging and removal is usually performed by a Digital Signal Processor (DSP). In this solution, the DC count component of the signal is averaged over a relatively long time frame. The average is then subtracted from the

wanted signal. It is broadly equivalent to AC coupling and so can potentially introduce distortion. However, it does have the advantage that relatively long average and time (and hence very low cut off frequencies) can be achieved without the need for high impedance design and/or large value coupling capacitors.

Taking the example of an IQ modulated signal, two consecutive symbols are combined into I and Q signals. Thus I and Q signals are produced from the received signal in the IQ demodulator, on the basis of which a decision is made in the receiver as to which symbol pair (00, 01, 10, 11) has been transmitted. The decision on whether the transmitted symbol is 0 or 1 is made on the basis on the voltage level of the demodulated signal. DC offset can occur in both I and Q signals, which can lead to a wrong decision being made in the receiver as to the signal pair transmitted. In an extreme case, even the error correction logic of the receiver cannot correct the information that has got a faulty expression. In some prior art solutions, an attempt is made to express the signal of the reception channel in spite of high interfering DC offset. However, the drawback of these solutions is the fact that they only operate in situations in which the disturbing DC offset is constant or changes very slowly. In situations in which the powers of the signals in the adjacent channels vary quickly the disturbing DC offset also change quickly whereby the prior art solutions are not capable of fully eliminating disturbance caused by DC offset. So whilst the prior art solutions are effective in mitigating DC offset in certain circumstances, such solutions do not satisfactorily tackle the problem across a wide range of differing received signal conditions.

Accordingly, the present invention provides a method of operating DC offset correction means of a direct conversion receiver of a portable radio communication apparatus comprising an RF front end adapted to down convert a received radio communication signal to a down converted IF signal,

the method comprising monitoring at least one criterion of the radio communication signal and providing a signal responsive to said at least one monitored criterion for controlling the input of the down converted IF signal to the DC offset corrections means.

By means of the invention, there is much lower audio distortion compared to blind DC offset correction because the AC coupling is only used when the distortion it introduces is masked by distortion caused by noise. Low-distortion DC coupling is used for strong wanted signals in which case the DC offsets are less significant compared to the signal. DC offset correction is switched into circuit when the signal is weak and the receiver's noise dominates the demodulator output distortion. In this case the DC offsets are usually larger than the wanted signal and so are removed by the present invention.

The apparatus is simple to implement, usually requiring only one coupling stage. The settling time is thus quicker than in prior art arrangements.

The invention will now be described by way of example with reference to the accompanying drawing which is a schematic block diagram of a preferred embodiment in accordance with the present invention.

Referring to the accompanying drawing, there is shown an RF front-end (1) which provides a down converted zero-IF output signal consisting of two phase I (in phase) and Q (quadrature) signals. These signals consist of both a wanted signal and a time variant DC offset which is produced by 2^{nd} order mixing effect and spurious AM demodulation. At low signal levels, the wanted signal is very small, and the DC offset dominates. The DC offsets on I and Q must therefore be removed in order to be able to amplify and demodulate the wanted signals in the IF stages (4). Under these conditions of low signal

levels, switches (3) under the control of comparator (5) are enabled in the position shown in the diagram thereby providing AC coupling of the I and Q into the IF stages. This removes the DC offset. The AC coupling is switched in or out of circuit according to the Received Signal Strength Indication (RSSI.)

At low carrier-to-noise ratios (CNR) the noise from the RF front-end (1) dominates the Signal to Noise and Distortion Ratio (SINAD) at the output from the FM detector. It is found that for wide band FM (eg. Modulation index β > 0.58) any distortion introduced by AC coupling generally tends to be masked by the noise from the system.

The RSSI is output from the IF stages and is coupled to a comparator (5) with hysteresis which is fed with a reference voltage corresponding to a threshold voltage for tripping the switches (3). This threshold value can be changed if required depending on differing requirements of particular applications. At low signal levels the comparator (5) holds switches (3) in the AC coupling position, the signal being coupled via capacitors (2). As previously mentioned, DC offset is particularly problematic at low CNR if the modulation index is low. The modulation index being given by $\beta = \dfrac{\textit{deviation}}{\textit{modulation freq}}$. The reason for this is that the lower value of β, the greater the power in the carrier. Since the carrier is a DC term, DC offset is damaging to it, in that it tends to cancel out the carrier term which thus causes distortion to it.

If the signal strength increases, hence increasing the SNR at the output from the demodulator, the distortion introduced by the AC coupling limits the ultimate SNR and SINAD (Signal to Noise Plus Distortion Ratio which is determined by the whole receiver itself) which can be obtained. Once the RSSI exceeds the threshold voltage, comparator (5) changes the position of

the switches (3) to disconnect the down converted signals from AC coupling and thus enable DC coupling. The signal is now much larger than the DC offsets so the distortion produced by the DC offsets is minimal. The SINAD of the demodulator output is much improved because the carrier term in the FM signal is preserved. This exploits the observation that there is a tendency for the signal to be noise dominated in weak signals and distortion limited in strong signals. In the case of a FM detector, SINAD provides a reliable indication corresponding to how good the signal is at the output of the detector.

Thus the invention provides a way of obtaining high sensitivity at low levels in the presence of relatively large DC offsets, but good quality (high SNR demodulated output at high CNRs) where the signal dominates over the DC offsets.

The invention has particular application to narrow band FM receivers and employs AC coupling in its preferred embodiments.

In an alternative embodiment, it is possible to provide the DC offset correction using a servo loop which is switched out at high SNR and activated at low SNR.

The present invention may be embodied in other specific forms without departing from its essential attributes. Accordingly reference should be made to the appended claims and other general statement's herein rather than to the foregoing specific description as indicating the scope of invention.

Furthermore, each feature disclosed in this specification (which term includes the claims) and/or shown in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features. In this regard, the

invention includes any novel features or combination of features disclosed herein either explicitly or any generalisation thereof irrespective of whether or not it relates to the claimed invention or mitigates any or all of the problems addressed.

The appended abstract as filed herewith is included in the specification by reference.

Claims

1. A method of operating DC offset correction means of a direct conversion receiver of a portable radio communication apparatus comprising an RF front end adapted to down convert a received radio communication signal to a down converted IF signal, the method comprising monitoring at least one criterion of the radio communication signal and providing a signal responsive to said at least one monitored criterion for controlling the input of the down converted IF signal to the DC offset corrections means.

2. A method according to claim 1, wherein one of said at least one monitored criteria is indicative of the received signal strength.

3. A method according to claim 1, wherein one of said at least one monitored criteria is indicative of the received signal quality.

4. A method for controlling DC offset correction in a direct conversion receiver of a portable radio communication apparatus the receiver having means for down converting a received radio frequency signal to a down converted signal, the method comprising measuring the signal strength of the received signal, providing a signal indicative of the signal strength of the received signal, comparing said signal indicative of the signal strength of the received signal to a predetermined threshold value of signal strength and applying DC offset correction for correcting the down converted signal if said signal indicative of the signal strength of the received signal is below the predetermined threshold and disconnecting DC offset correction for the down converted signal if the signal indicative of the signal strength of the received signal exceeds the predetermined threshold value of the signal strength.

5. A method for controlling DC offset correction means of a direct conversion receiver comprising monitoring at least one criterion of a received signal and providing a signal responsive to the at least one monitored criterion for enabling or disabling the DC offset means.

6. A method according to claim 5 comprising comparing the signal strength of the received frequency signal with a predetermined threshold and providing a signal responsive to the compared signal for controlling the operation of the DC offset means.

7. Apparatus for compensating DC offset of a received signal in a receiver of a portable radio communication device, the apparatus comprising means for receiving the received signal, means for providing a signal indicative of the signal strength of the received signal, a comparator for comparing said signal indicative of the signal strength with a predetermined signal strength level, and DC offset correction means arranged to effect DC offset correction of the received signal if the comparator provides that the received signal strength is below the predetermined signal strength level.

8. Apparatus for controlling the operation of a DC offset of a receiver, the apparatus comprising means for monitoring at least one criterion of the radio communication signal and means for providing a signal responsive to said at least one monitored criterion for controlling the input to the DC offset means.

9. A direct conversion receiver of a portable radio communication apparatus comprising an RF front end for down converting a received frequency signal to an intermediate frequency signal for down stream intermediate frequency processing, and having DC offset correction means arranged to be activated in response to a signal provided by a comparator

wherein the received signal strength is compared with a predetermined signal strength level.

10. A method for controlling DC offset substantially as hereinbefore described with reference to and/or as shown in the accompanying drawing.

11. Apparatus for controlling DC offset substantially as hereinbefore described with reference to and/or as shown in the accompanying drawing.

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Application No:	GB 9903259.1	**Examiner:**	Keith Williams
Claims searched:	1-11	**Date of search:**	1 September 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H4P (PAD, PAL, PAN, PAR)

Int Cl (Ed.6): H04L 25/06, 27/14, 27/38

Other: Online EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2327834 A	NEC Corp. - see abstract	1,4,5,7,8, 9
X	GB 2274759 A	Nokia Mobile Phones - see abstract (& EP 0611057, US 5754595)	1,4,5,7,8, 9
X	GB 2256985 A	Motorola Inc. - see abstract (& WO 92/11703, US 5212826)	1,4,5,7,8, 9
X	EP 0719013 A2	AT&T Corp. - see abstract (& US 5724653)	1,4,5,7,8, 9
X	EP 0693750 A2	Quantum Corp. - see abstract (& US 5459679)	1,4,5,7,8, 9
X	EP 0692894 A2	NEC Corp. - see abstract	1,4,5,7,8, 9
X	EP 0594894 A1	Alcatel NV - see abstract; page 4, lines 4-27 (& US 5422889)	1,4,5,7,8, 9
X	EP 0474615 A2	Telefon. Ericsson - see abstract	1,4,5,7,8, 9
X	EP 0430480 A2	Motorola Inc. - see column 3, lines 30-38	1,4,5,7,8, 9

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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Application No: GB 9903259.1
Claims searched: 1-11

Examiner: Keith Williams
Date of search: 1 September 1999

Category	Identity of document and relevant passage		Relevant to claims
X	WO 98/16039 A1	Harris Corp. - see abstract (& EP 0865699)	1,4,5,7,8, 9
X	WO 98/10523 A1	Philips Electronics - see abstract (& EP 0865686)	1,4,5,7,8, 9
X	WO 98/06172 A1	Zenith Electronics Corp. - see abstract (& US 5699011)	1,4,5,7,8, 9
X	WO 98/01981 A1	Telefon. Ericsson - see abstract	1,4,5,7,8, 9
X	US 5748681	Lucent Technologies Inc. - see abstract	1,4,5,7,8, 9

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.